

Trends in Vacuum Technology and Pneumatics in the Context of Digitalization

Dr. Kurt Schmalz

J. Schmalz GmbH, Aacher Str. 29, D-2293 Glatten, Germany,
E-mail: kurt.schmalz@schmalz.de

Dipl.-Ing. Albrecht Winter

J. Schmalz GmbH, Aacher Str. 29, D-2293 Glatten, Germany,
E-mail: albrecht.winter@schmalz.de

Abstract

Digitalization is finding its way into production and machine-building. Autonomous, self-optimizing and highly interconnected units will determine the functionality of machines and production facilities. Communication and automation layout will fundamentally change, data will be more and more the base for new business models.

Innovation is determining pneumatics and handling technology. The innovation topics performance improvement, modular and mechatronic design of systems, sustainability and efficiency are keeping pneumatics and vacuum technology on the pathway of success. But is the technology field also prepared for the tremendous challenges caused by the digitalization?

This paper is focusing on the significance of digitalization for fluid technology, especially for pneumatics and vacuum technology.

The new concepts of digitalization and autonomization are based on the Internet of Things with open Communication of cyber-physical systems. These cyber-physical systems are able to react autonomously. Cyber-physical systems can collect, interpret and analyse data and transfer it into valuable information. Based on these data, cyber-physical systems will provide services to all participants of the smart factory. There will be a digital image inside the factory cloud, which is the base of new business models.

Systems of pneumatics, vacuum technology and hydraulics will play a core role in this world. They are placed directly at the interface to the real technical process, they have direct contact with the workpieces, they are collecting multitude of sensor data and are evaluating it, they have functionality like Condition Monitoring and Energy Efficiency optimization on board and are able to communicate with the world of automation.

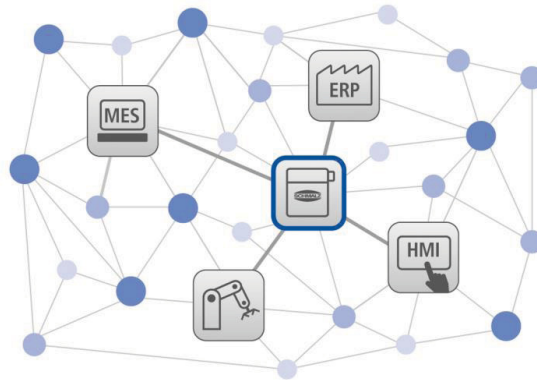


Figure 1: Open communication architecture in the new automation architecture

Source Schmalz

This paper will show, that the innovation trends of the last years are supporting the way towards digitalization and Industrial Internet of Things. There are already a lot of different approaches to establish vacuum and pneumatic systems as adequate elements of the digitalized world.

It will also be shown, that fluid technology still is facing tremendous challenges. It will be not sufficient to equip the systems with more functionality and better communication. It will be essential, that from the interpretation and correlation of data will be derived valuable services with real customer benefit.

This should happen under control of the vendors of smart field devices in fluid technology. Then it will be possible to turn this new kind of value generation also into new business models.

KEYWORDS: Pneumatics, vacuum technology, digitalization, Industry 4.0

1. Introduction

Pneumatics and vacuum technology covers a wide range of industrial applications in all kind of industry segments. This is not only based on the advantages of pneumatic components like ease of use, robustness, compactness and cost advantages. Innovation impulses, which are set from industrial suppliers as well as from research institutes, were always important in order to keep pneumatics fitting into the changing world of industrial production.

The innovation areas of pneumatics and vacuum Technology are determined by performance improvement, by development of components in modular design, by mechatronic design of components and systems, by sustainability (resource efficiency and energy efficiency), by focus on industry segment specific developments and digitalization.

Most of these innovation paths are pursued intensively since years. Papers regarding the trend towards systems design, towards mechatronics and efficiency are were published like /1/ and /2/. As result of intensive ongoing innovation, pneumatics and vacuum technology remain on a path of growth and economic success – even in a difficult surrounding.

Approximately since two years a new innovation path in production and engineering is challenging pneumatics and vacuum technology as well as the complete fluid technology: the digitalization of manufacturing and smart data handling. “Smart factory”, “Industrial Internet of Things”, “Industry 4.0” and “Autonomization” are key-words of this innovation path. This paper will mainly concentrate on this innovation topic.

The new concepts of digitalization and are based on the Internet of Things with open Communication. This concept is transferred to the world of manufacturing and called “Industry 4.0” or Industrial Internet of Things IloT” Base of the concept are cyber-physical which are able to react autonomously. Cyber-physical systems can collect, interpret and analys data and transfer it into valuable information. Based on these data, cyber-physical systems will provide services to all participants of the smart factory. There will be a digital image inside the factory cloud, which is the base of new business models.

The segment of pneumatics and vacuum technology is developing base technologies for digitalization already since years:

- Mechatronic embedded systems with broad communication capabilities are the pre-requisite for digitalization and are the predecessor of Cyber-Physical Systems, like shown in /3/.
- Valuable data generation is also pre-requisite for digitalization and intelligent data management in production. Pneumatics and vacuum systems are integrating Condition Monitoring functions and Predictive Maintenance capabilities. Already in 2008 the first principle papers and implementations could be found /4/.

These are base technologies to make the components “Industry-4.0-ready” The challenge on the way towards digitalization of production is bigger. When looking to the developments in automation and production software of the last years, this becomes clear: The idea of collecting all relevant data from production environment, operating the production and the product itself into one industrial cloud will lead to complete new services and business models.

One important example was released in March 2015: Data Mind Sphere – the Siemens Cloud for Industry is an open platform and will open each OEM to integrate their technology and create new applications. Currently MindSphere is in the pilot phase, see /5/ and /6/

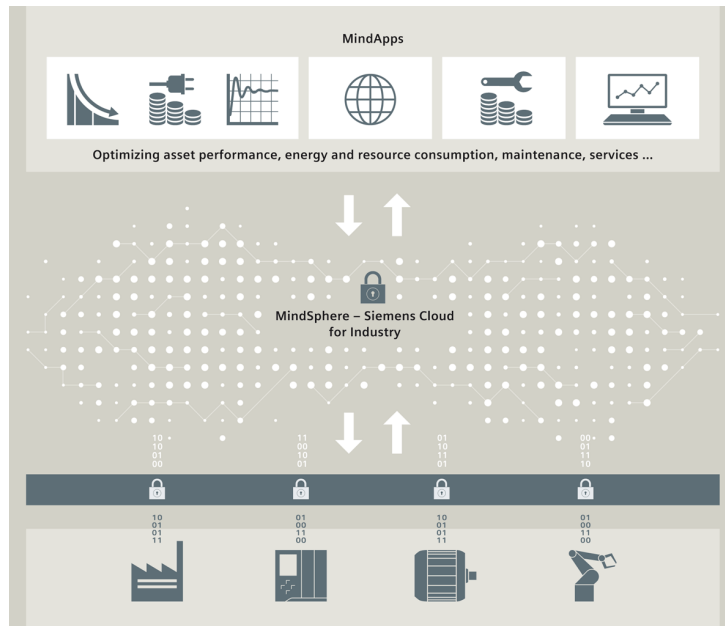


Figure 2: MindSphere – Siemens Cloud for Industry. Source: Siemens /5/

Not only big automation companies are on the way to establish products for digitalization. Big machine builders do not want to leave the Smart Factory to third parties. Latest example is the foundation of TRUMPF, a high-technology company which provides manufacturing solutions in the fields of machine tools, lasers and electronics. Axoom GmbH was founded in October 2015 in order to develop the digital business platform for manufacturing companies. The open, vendor-neutral platform enables reliable data transportation as well as data storage and analysis. At the same time, it offers solution modules for seamless order processing within a production operation. /7/

Mathias Kammüller, Dr. Eng. Head of Machine Tools Division at TRUMPF says: “With AXOOM we are thinking outside the box and creating a new, digital, and open business platform that covers the entire value chain and is manufacturer-independent. Machines and systems from a variety of providers working together intelligently – this is the future. AXOOM does not stop at the walls of the production shop, but rather, supports users from supplier to end customer. With its modular design, AXOOM enables production shops to move toward Industry 4.0 at their own pace and step by step” /8/



Figure 3: AXOOM – Digital platform for production. Source: TRUMPF /7/

The challenge is clear: Pneumatics and vacuum technology systems as well as all fluid technology systems have to fit into this world: Field devices in this new world – called

Smart Field Devices – must create valuable data and derive services with customer benefit.

Pneumatics and fluid technology companies meet the challenge: From an organizational point of view Parker Hannifin Cooperation is showing one example: The board of directors created a new position “Vice President - eBusiness, IoT and Services”, starting September 1, 2015. This new position reinforces Parker’s increased focus on cloud-based applications that enable customers to connect to products for remote control, monitoring, and business analytics. /9/

From a technological point of view, a lot of the current trends in pneumatics and vacuum technology are contributing to digitalization. This will be shown in the next chapters.

2. Digital technologies in engineering of pneumatics and vacuum technology

2.1. Simulation in the application engineering process

One pre-requisite of the digitalization is the availability of a digital image of each component. Seamless engineering processes are using one data platform for design and simulation. Design models are the representation of the shape, simulation models are the representation of the function. If an engineering process is digital and seamless, optimization and direct manufacturing (e.g. with additive methods) are part of it.

In vacuum handling technology, one aspect regarding vacuum generation is the most important: To generate vacuum with highest efficiency at the individual application specific working point. Paper /10/ shows that simulation technology combined with additive manufacturing technology can meet these requirements:

By use of modern CFD simulation tools, ejector nozzles can be designed with optimized flow characteristics to suit specific operating points leading to highly efficient vacuum generation for each individual application. New manufacturing techniques, such as additive manufacturing, enable that these specialized nozzle geometries can now be produced and validated immediately causing low development and production costs in combination with short delivery times.

In handling applications, these specialized ejector-nozzles permit an increase in energy efficiency of up to 40% compared to a standardized ejector that, due to surrounding conditions, must work at a non-optimal operating point. As a result of this increase in

efficiency while production costs remain virtually unchanged, the total cost of ownership of these nozzles can be significantly lower.

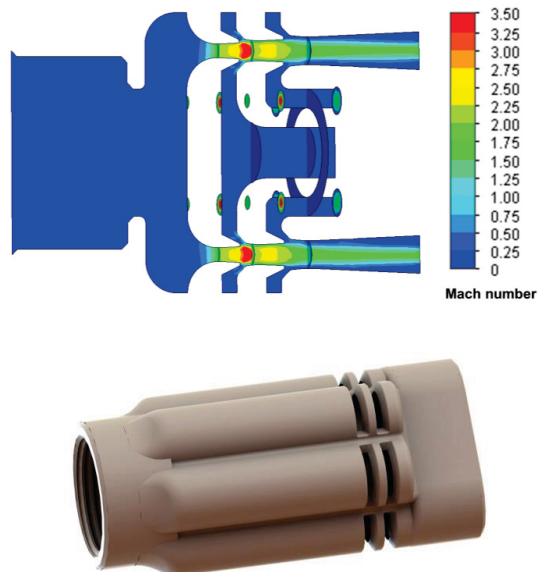


Figure 4: A specialized multi-stage ejector in CFD design (top) and in final production by means of additive manufacturing (bottom)

Source: J. Schmalz GmbH /10/

2.2. Configuration and simulation in systems design

Another field in creation of the digital image can be found in the system design: Companies in the field of pneumatics offer to their own systems engineers and to the customers (by using their internet portals) the possibility of configuration and simulation of complete systems. Typical example is the configuration and calculation of handling systems: Market leaders like Aventics and Festo are offering software applications via their homepages. Aventics e.g. has developed the “Small Handling Configurator”. At the beginning, application specific parameters like load, working area and cycle time has to be entered in order to get the best proposals for the handling solution.

Small Handling Configurator

AVENTICS 

Get to your Individual Handling System Quickly

- Handling systems with guided and rotary actuators and the corresponding accessories can be individually specified
 - Basic Layout
 - Payload
 - Strokes
 - Cycle time
- Intuitive layout
- Quick menu access
- Personal work spaces
- Complete documentation is generated individually
 - Configuration data (PDF)
 - Part lists
 - 2D-/3D-CAD-Data



© AVENTICS 2015

Alle Rechte vorbehalten, auch bzgl. jeder Verfügung, Verwendung, Reproduktion, Bearbeitung, Weitergabe sowie für den Fall von Schutzrechtsanmeldungen

Figure 5: Small Handling Configurator. Source: Aventics

With the Handling Guide Online, Festo also is offering configuration possibilities since the first quarter of 2015, but is focusing more on electric drives: The engineer selects the desired type of handling system and enters the application data. Then he selects the most suitable handling system from the suggestions of the tool. The engineer then configures the selected system with additional options in accordance with his own requirements.

2.3. Importance of the digital image

These tools today are mainly focusing on the design process in order to save engineering costs and to facilitate the ordering process. The possibilities of these tools are much bigger: A complete digital image for the system can be created: Already today, data sheets and CAD models are created, but calculation and simulation is done only in the background. Simulation and calculation models, E-CAD macros and included control mechanism should be delivered also to the customer in a standardized format in order to obtain a complete digital image for the system. Already two years ago, Schmalz published in [11], how these requirements from digitalization will influence the engineering process of vacuum gripping systems.



Figure 6: Seamless and interlinked engineering of product and production.

Source: Siemens /12/

If a new product is designed, production engineering will use simulation on the base of the digital image of the product and the digital image of the production devices. E.g. the dimensioning and layout of a handling and gripping system for the press shop of an automotive production then will be done in parallel to the design of the new car itself. At the end of the design process, product and production devices are perfect harmonized and production engineering already is finalized. Smart field devices therefore have to have the complete digital image in order to generate these benefits.

3. Digital technologies inside the products in pneumatics and vacuum technology

3.1. Embedded systems

Mechatronic integration and embedded systems in the fields of pneumatics and vacuum technology is an ongoing development since more than 20 years, see e.g. a paper from 1993 regarding valve terminals with integrated control electronics. /13/. The developments until today in this field were enormous: In the beginning, embedded systems were integrated as “stupid” slaves, characterized through direct access to bits and bytes. The development went to intelligent subsystems with a big portion of software onboard, characterized through functions and function block philosophy. Today’s developments are going to have comprehensive software for configuration and parametrization of the embedded devices – also directly on-site with mobile devices, see e.g. figure 7.

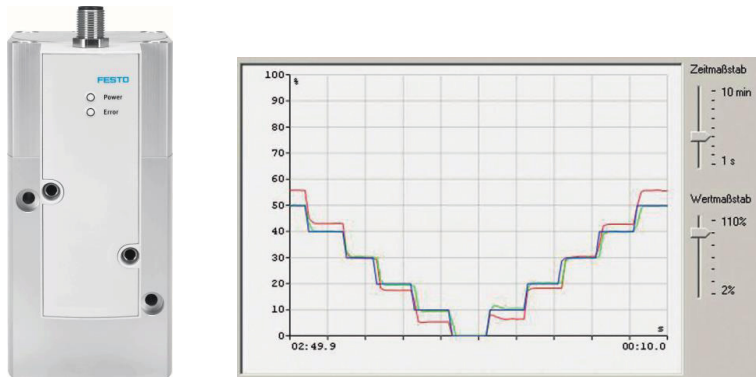


Figure 7: Proportional Valve VPPX with configuration Software. Source: Festo

Where are embedded systems going anyway in order to fit best into a digitalized world?

3.2. Smart field devices – Cyber-physical systems

Base of technologies and methods in smart factories (digitalized manufacturing) are “cyber-physical systems CPS”. Embedded systems are predecessors of cyber-physical systems. In order to work as real cyber-physical system, they have to be complemented with additional features:

- Unique identification in the world-wide net (e.g. Separate identity through IP address)
- Besides the real object there has to be available a complete digital image (onboard or in the cloud), see chapter 2.3
- Creation of valuable data related to the application, derived from intelligent sensoric and the real connection to the technical process. Valuable data e.g. can be traffic lights in a condition monitoring system, which are derived from a big portion of sensor data.
- Capability to provide own services in the net. Such a service could be for example a re-calibration of a sensor or a predictive maintenance demand of the device.

4. Creation of valuable data

4.1. Mechatronic function integration

The availability of embedded systems led to “function integration” into field devices. Function integration in pneumatics often is understood as a compilation of various functions into one modular device, which in before where distributed as single devices

at the complete machine. This is mainly directed to valve terminal concepts. Festo e.g. is consequently going the way to integrate various functions (switching valves, proportional valves, pressure control, positioning and soft-stop for pneumatic axes, sensor integration, start-up pressurization and safety functions) into pneumatic valve terminals /15/.

Real benefits are reached, when software function modules are added in order integrate functions, which in before could only be executed in higher levels of the automation hierarchy or which in before where not possible. In this case it is named real mechatronic function integration.

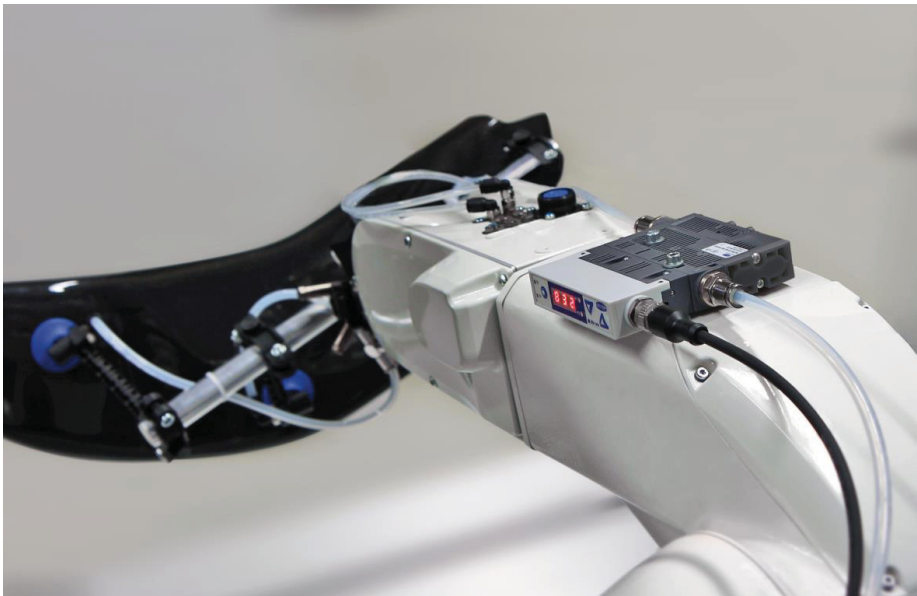


Figure 8: Vacuum Compact Ejector with mechatronic function integration.

Source: Schmalz

As typical example is the development of compact ejectors: Vacuum specialist Schmalz started already years ago with the mechanical integration of the efficient nozzle technology, pneumatic valves for switching functions and embedded electronics. By adding software based functions and sensors into the device, additional benefits for the application could be reached:

- Automatic air saving function for economic operation. This reduces the amount of compressed air consumption by up to 80 percent compared to similar ejectors without embedded controllers. . If no vacuum is required at the moment, this function is simply switched off by the compressed air generator

- Automatic, strength-adjustable blow-off function. This allows for even quicker pickup of parts and increases the overall dynamics of the process
- Energy monitoring and condition monitoring of the complete gripping process: By calculating and monitoring the energy consumption, it is possible to run the complete application in energy-optimized mode.
- Condition Monitoring and Predictive maintenance: Their diagnostic and forecasting functions derive information regarding the condition of the unit (e.g. wear or contamination) and detect subtle changes and imminent malfunctions. This enables avoidance of unplanned machine downtime and an increase in system availability

These comprehensive energy and process control functions are integrated in the intelligent compact ejectors and obviously are going into the field of valuable data provision: The result of these function is not going into the real-time control of the machine (PLC level), these data are needed in the factory clouds shown in the introduction.

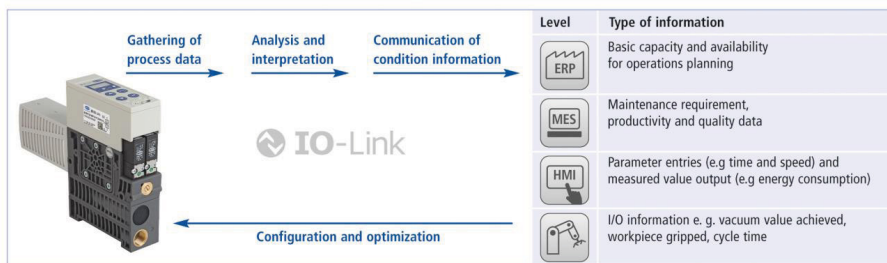


Figure 9: Different level of data communication from smart field devices

Source: Schmalz

4.2. The importance of valuable data

As it could be seen from the introduction, all new possibilities in the digitalized factory are based on data. Industrial production processes will be optimized and new services can be generated by interpreting and analyzing data out of the technical process, by interrelation to other data from neighbor processes (commercial, logistic or technical). Base of all these possibilities are valuable data.

Pneumatics and vacuum technology is in a comfortable position, because smart field devices of this technology are directly interlinked to the technical process, have already intelligence for data interpretation on board as well as communication possibilities. The example of vacuum compact ejectors is confirming this.

In social media platforms, shops and search engines data are the base of business models. The same development already started for manufacturing. Also in the production environment data has to be understood as economic asset. Data will be the base of new business models like pay per unit or pay per service.

The new challenges of the digitalized factory result in the necessity of data interpretation and data analytics. Pneumatics and vacuum technology has to develop such methods for various applications. Application specific algorithms, trend analysis over time, statistic functions or standard mathematic functions are used to derive out of a nondescript big quantity of data valuable data.

4.3. Condition Monitoring and Predictive Maintenance

The best elaborated technology field in the area of data handling is the already mentioned example of Condition monitoring and Predictive Maintenance. VDMA – Verband deutscher Maschinen- und Anlagenbau e.V. published the standard “VDMA 24586: Fieldbus Neutral Reference Architecture for Condition Monitoring in Factory Automation” /14/. The base ideas of this standard were already published in 2008 /4/. In consequence, a group of industrial companies and universities under the guidance of the VDMA was founded. It was a complete new approach not to standardize technical features or field bus specifications, but to work out reference architecture for Condition Monitoring and Predictive Maintenance. Core of the standard are the three views to Condition Monitoring (see figure 10), the uniform representation of the condition monitoring function block and the clear definition of data.

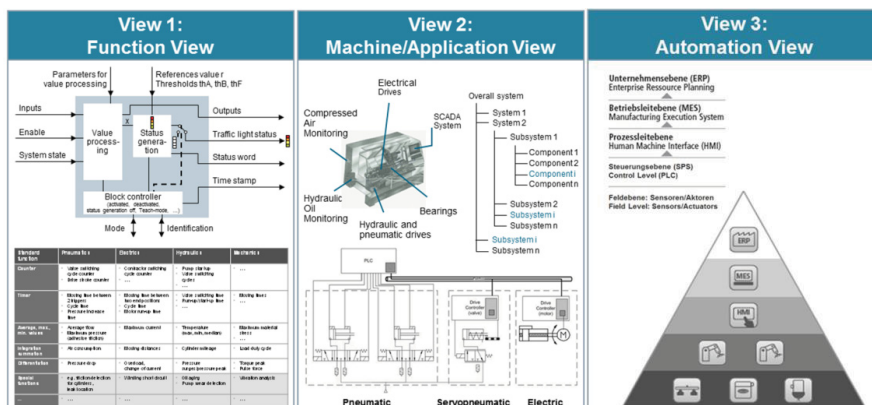


Figure 10: Three views to condition monitoring

On the base of the defined methods for building condition monitoring function blocks, a comprehensive collection of examples from different technologies are described in deep detail. Figure 11 shows one example in pneumatics out of the VDMA standard. Each of these examples indicates methods of generating valuable data.

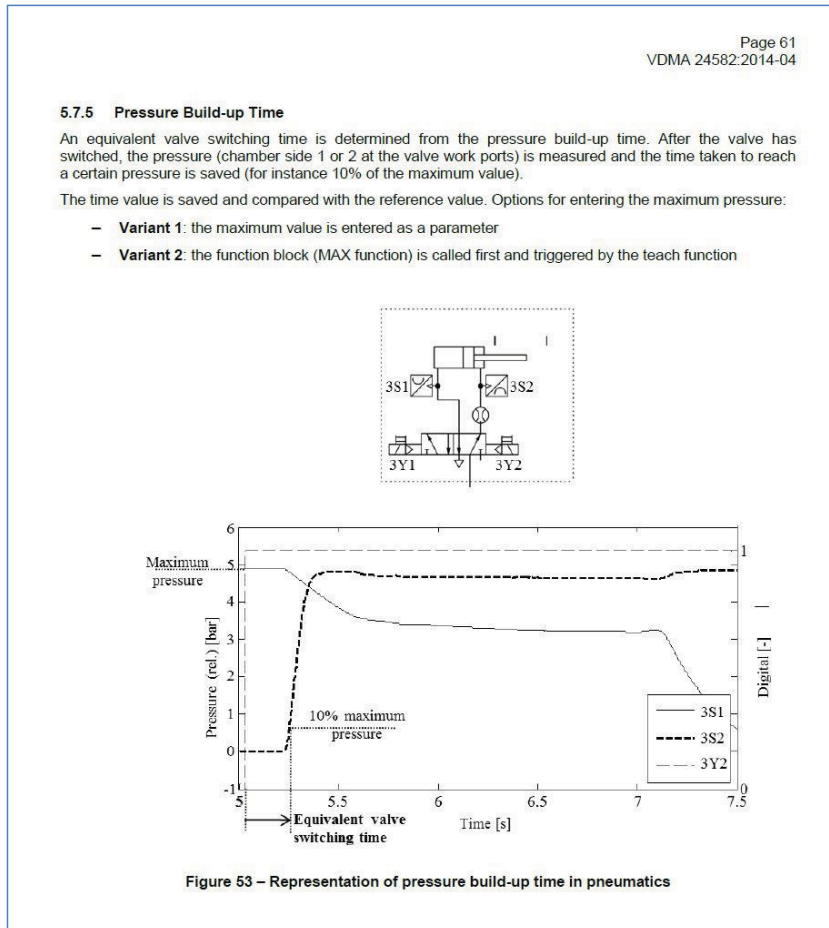


Figure 11: Example of condition monitoring algorithm as part of VDMA 24582.

Source VDMA /14/

In order to strengthen the importance of pneumatic and vacuum technology, it will be necessary to found more such initiatives from industry and research institutes. Possible areas could be the general topic of data analytics in regards to different application, but also energy management und safety functionality in applications.

5. New automation and communication concepts

5.1. Decentralized control and data handling

Pneumatic valve terminals with integrated electronics are pre-determined to act as smart field devices (in consequence as cyber-physical systems).

Aventics e.g. has developed the Advanced Electronic System (AES) as base for decentral data access, intelligent sensor integration and broad communication option. See figure 12 and reference /17/.

The step from embedded mechatronic devices into the direction to smart field devices includes three main features:

- Decentral autonomous configuration and control is possible.
- Raw sensor data are captured, interpreted, analyzed and transferred into valuable data (or software services). Raw data in this case e.g. could be the collection of time for an actuator to reach its end position. If this time will become longer and longer over a period, a smart field device will have the possibility to compare it to predefined thresholds, to co-relate it with the weight of individual work piece, to correlate it with the surrounding temperature and then create a maintenance request to the ERP system
- Communication for field devices until now was covered by field busses. Real-time communication here was the main issue, I/O-Link and Profibus are the main representative. If smart field devices will be integrated into the world of digitalized production and in open communication nets like shown in figure 1, this will not be enough. Other, non-real-time communication methods are necessary to be included into the smart field devices.

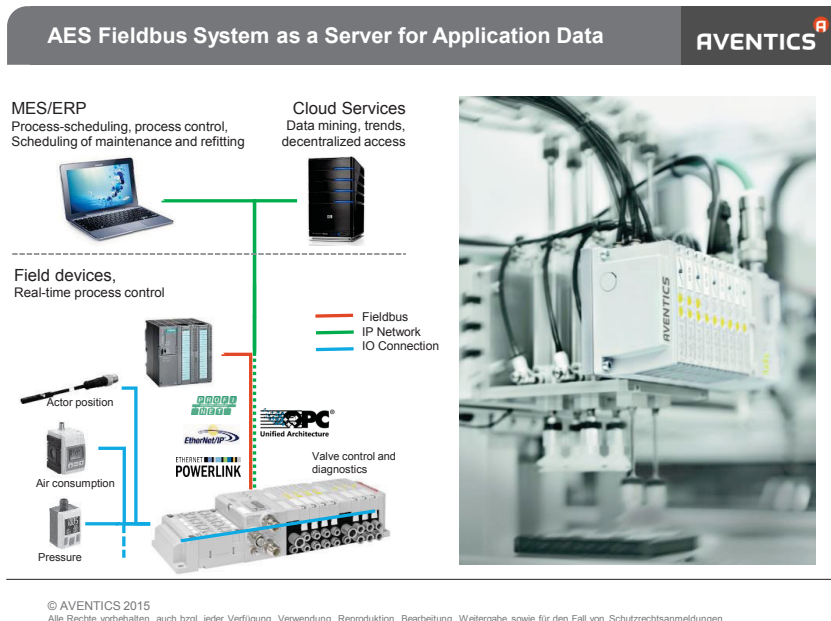


Figure 12: Valve electronic of latest generation enables decentral data access

Source: Aventics /17/

5.2. New Communication concepts

Digitalization needs new communication paths and new access to data. As seen in chapter 5.1, standard field bus communication will not any more meet all requirements of the digitalized world. In order to communicate directly between smart field device and e.g. an ERP system, other means are necessary. As a de facto standard, OPC UA is mostly used for data communication into the production cloud and for software services. This direct link is necessary e.g. to transfer a maintenance request directly from the gripper system to the ERP system, to order all necessary spare parts and to schedule the resources of the maintenance crew.

Additionally, other communication channels have to be established. Machine operators and maintenance people should have direct link to the digital image of each intelligent device of machines. Latest development in this field is the use of NFC (Near Field Communication) in industrial automation. NFC - originally developed for payment systems – is included in nearly each mobile device and allows a very cost effective realization of communication to each kind of devices. In 2015 the first industrial devices in vacuum technology with NFC came to the market: Schmalz pressure sensors and vacuum terminals.



Figure 13: Vacuum terminal and vacuum sensors with Near Field Communication

Source: Schmalz

The concept behind is not only to identify the components at the machine. Main benefit is the direct access to all data in the digital image (which is placed in the cloud). Manuals, settings, configuration values can be accessed immediately and used on-site for service, repair or replacement. In future, specific values also will be written into the devices. This will e.g. allow cloning the configuration settings in the case of exchange.

6. Future developments, summary and outlook

Innovation paths in the future will not only be software and data analytics. Profound mechanical engineering and innovative mechanical developments will be pre-requisite for further success of pneumatics and handling technology. But development of software and apps, data analytics and integration into any kind of clouds will be much more important as in the past and will be an additional path of generating revenue.

Therefore it is very important, that the industry segment of fluid technology does not leave this field to IT-oriented players in the market. It is necessary for fluid power companies to further develop the technical basis – Industry-4.0-compatible technology - like shown in this paper. It is also necessary for fluid power companies to develop new business models in order to generate revenue out of the data, which are generated in their own products.

This will be possible and there are already first attempts in this direction. Camozzi for example announced in November 2015 the idea of Camozzi Digital – an Industry 4.0 Maintenance Solutions, which is currently tested in some textile applications. Other companies in pneumatics and vacuum technology are in the pilot phase to develop the integration of their components into factory clouds like Axiom or MindSphere.

The cooperation of machine building companies, of pneumatics and vacuum system suppliers and research institutes is very important in this phase. Only with combined efforts the industry segment will benefit from the opportunities of the digitalization.

7. References

- /1/ Schnur, F., Fiedler, M. Pneumatics – Future through mechatronics design and Efficiency. 8th International Fluid Power Conference, March 26 -28, 2012, Dresden, Germany, p. 169-184
- /2/ Winter, A., Bredau, J. From Component Supplier to Solution Provider. 7th International Fluid Power Conference, March 22-24, 2010, Aachen, Germany, pp. 203–220.
- /3/ Post, P.: Smart Pneumatics for Intelligent Manufacturing, 9th International Fluid Power Conference, March 24 – 26, 2014, Aachen, Germany, http://www.ifk2014.de/index.php-folder_id=366&ses_id=1cdc39cdad18602d0355814326cc9e27.html
- /4/ Bredau, J., Winter, A., Post, P., Bauer, F. Condition Monitoring in Fluid Power Technology – A Comprehensive Approach. 6th International Fluid Power Conference, April 01-02, 2008, Dresden, Germany, pp. 211–240.
- /5/ Siemens to build open cloud platform for industrial customers. Siemens Press release Information no.: PR2015030152DFEN. Nuremberg, March 12, 2015
- /6/ Open cloud platform boosts digital service business for industrial customers. Siemens Press release Reference no.: PR2015100331DFEN. Nuremberg, October 8, 2015
- /7/ Machine manufacturer presents digital business platform "AXOOM" - Leibinger-Kammüller: "A key solution on the way to the Smart Factory". Press release TRUMPF GmbH + Co. KG, Ditzingen, October 21, 2015
- /8/ AXOOM homepage, January 10, 2016, <https://www.axoom.com/en/home/>
- /9/ E-business, Internet of Things (IoT) and Global Services to be key areas of growth. Press release Parker Hannifin Corporation, CLEVELAND, August 13, 2015

- /10/ Kuolt, H. et. al: Optimization of pneumatic vacuum generators – heading for energy-efficient handling processes, 10th International Fluid Power Conference, March 8 - 10, 2016, Dresden, Germany
- /11/ Winter, A.: Mechatronic System Engineering of Vacuum Gripping Systems. Conference Proceedings, 9th International Fluid Power Conference Aachen, March 24-26, 2014, Aachen, Germany, p 362 - 373
- /12/ Helmrich, Klaus: Auf dem Weg zu Industrie 4.0 – das Digital Enterprise. Nuremberg, November 24, 2015, Presentation at press conference sps ipc drives. [http://www.siemens.com/press/de/events/2015/processindustries-drives/2015-10-sps.php?content\[\]=DF&content\[\]=PD&content\[\]=EM](http://www.siemens.com/press/de/events/2015/processindustries-drives/2015-10-sps.php?content[]=DF&content[]=PD&content[]=EM)
- /13/ Staniczek, Dieter: Installationssparende Lösungen mit busfähiger und programmierbarer Pneumatik. 9. Fachtagung Hydraulik und Pneumatik vom 22--23- September 1993 in Dresden - als Ms. gedr. - Dresden : Techn. Univ., [1993] S. 549 – 570
- /14/ Fieldbus Neutral Reference Architecture for Condition Monitoring in Factory Automation. VDMA 24582, VDMA Verband Deutscher Maschinen- und Anlagenbau e.V., Frankfurt/Main, Beuth Verlag, Berlin, April 2014.
- /15/ Wahl, Philipp: White Paper Function integration saves time all round. Festo AG & Co. KG, Esslingen, Germany, 2015
- /16/ New partnership started between Microsoft and Camozzi in view of Industry 4.0. Press release Camozzi Group, MILAN, 18 November 2015. <http://www.camozzigroup.com/en/camozzigroup/media-press/news/marzoli-remote-maintenance-new-technological-platform-%C2%ABsigned%C2%BB-by-camozzi-microsoft>
- /17/ Intelligente Pneumatik: Aventics und die Industrie 4.0, www.fluid.de , 16.10.2015. verlag moderne industrie, Landsberg, Germany.

